PROPOSAL FOR THE STUDY OF THE DEMOGRAPHY AND POPULATION GENETICS OF FIVE SPECIES OF CORAL ON NINGALOO REEF, WESTERN AUSTRALIA.

Kelley Holborn
DEPARTMENT OF ZOOLOGY, UNIVERSITY OF WESTERN AUSTRALIA
NEDLANDS, CRAWLEY, WA 6009

Background

The Ningaloo Reef was declared a marine park in 1987 because of its rich coral communities. In the late 1970's and early 1980's its beauty rivalled that of the Great Barrier Reef. However, since about 1988, much of Ningaloo has been devastated by *Drupella cornus*. Coral cover in the back-reef zone (i.e. the shallow reef flats adjacent to the sandy lagoon) has been reduced by more than 75% in two thirds of the reef (Stoddart, 1989). The areas most badly affected by the outbreaks in 1988/89 were Ned's Camp, Mesa Camp, Osprey Bay, Sandy Bay and Winderabandi Point. Since then less than 1% live coral cover has been observed in these places.

Populations or species which are devastated by catastrophic disturbances may be replaced in time through recolonisation. Recolonisation and regeneration of an area depend upon a sufficient supply of viable recruits. The rates of recruitment, survivorship and growth will determine the time taken for the population to restore its pre-disturbance structure. These will depend upon a number of factors:

i. Mode and timing of reproduction of prospective colonising species.
ii. Mode of fertilisation of parents.
iii. Dispersal capability of prospective recruits.
iv. Survival and growth to sexual maturity of recruits.
v. The degree of connectedness of populations supplying the recruits.

These factors will vary for different species of coral so that the rates of recolonisation should continuously differ among species. For example, corals utilise a diverse set of reproductive options, both sexual and asexual. Consequently, mode of reproduction is a major determinant of the spatial and temporal limits of a species' niche. This project will, therefore, focus on which types of corals are best at recolonising decimated areas and which life history characteristics are most important in producing them.

Aims

In an attempt to understand the process of recovery following devastation by *Drupella cornus*, I plan to study the life history, patterns of recruitment, and genetic subdivision of corals at Ningaloo Reef. The specific aims of the project are:

i. To examine the patterns of recruitment in five species of corals over two years. Seasonality of recruitment, species composition and abundance over time, will be investigated.
ii. To quantify the growth and mortality rates of these young corals using demographic techniques. This will enable estimates to be made regarding the length of the recovery process.

iii. To establish an electrophoretic key, using gene markers, whereby recruits can be identified at a few days of age. The identification of recruits before six months of age has previously been impossible using current taxonomic criteria.
iv. To quantify levels and patterns of genotypic diversity for the same five species over the length of Ningaloo Reef. This information will be used to test independently the importance of mode of reproduction (sexual versus asexual) and mode of fertilisation (internal versus external). It will also provide estimates of gene flow and thus information on the actual dispersal of species.
v. To examine the relationships between life-history characteristics and levels of genetic variation.

Major aspects of the life histories (recruitment rates, growth, mortality and mode of reproduction) and population genetics will be quantified for *Acropora hyacinthus, A. digitifera, Montipora aequituberculata, Pocillopora damicornis and Seriatopora hystrix*. These species were chosen on their following characteristics:-

i. Ease of identification (L. Marsh 1991 pers. comm.)
ii. Different growth forms were chosen because adult *D. cornus* prefer tabular corals (e.g., *A. hyacinthus* and *M. aequituberculata*) whilst the juveniles prefer the digitate corals (e.g. *A. digitifera*) (Forde and Simpson, 1989).
iii. Different modes of reproduction - *Pocillopora damicornis* is able to produce asexual planulae (Stoddart, 1983) whilst the remaining species almost exclusively reproduce sexually.
iv. Different modes of fertilisation - *Acropora hyacinthus, A. digitifera* and *Montipora aequituberculata* broadcast their gametes whilst *P. damicornis* and *S. hystrix* brood their larvae (Ayre and Resing, 1986; Stoddart 1983; Wallace, 1985; Wallace and Bull, 1981).

Investigation of coral life histories

Sixty-four terracotta settling tiles (150mm x 150mm), bolted onto steel racks, have been set up at six sites on the back reef of Ningaloo. These tiles were chosen because of the abundance of spat they attract and because they are cheap, readily available, have minimal preparation and provide a standard surface easily replicated within and between experiments (Harriott and Fisk, 1987; C. Simpson pers. comm.). The experimental design is a nested orthogonal design (Figure 1).

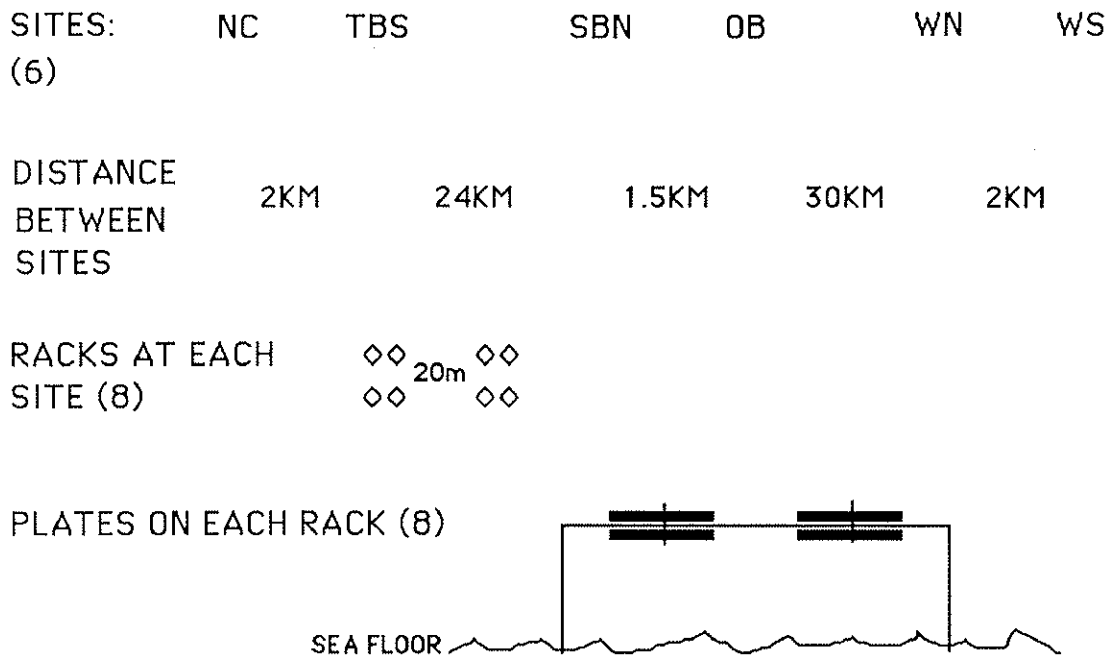

Figure I. Design and Placement of Settlement Racks and Tiles.
NC=Ned's Camp; TBS=T-Bone Sth; SBN=Sandy Bay Nth; OB=Osprey Bay; WN=Winderabandi Nth; WS=Winderabandi Sth.

At each site, four racks of 4 pairs of plates have been placed approximately 20 cm above the substrate. Plates are in pairs since it allows the coral recruits a choice of orientation for their attachment. Previous studies have shown that recruits prefer the underside of plates (Wallace and Bull, 1981; C. Simpson 1991 pers. comm.) or the gap between pairs of plates (Harriott and Fisk, 1987). This design was chosen to allow for the detection of different scales of recruitment. All six sites share the following characteristics:-

i. They share similar histories of devastation by *D. cornus*.
ii. Coral cover at each site is as close to zero as possible.
iii. Sites are geographically placed so as to provide information on spatial recruitment differences.

In addition to these six sites, settling plates have been placed at an extra three sites (viz: Tantabiddi, Coral Bay and Pelican Point) which have above 40% live coral cover. This is to asses the potential pool of recruits from areas which have not been devastated by *D. cornus*.

Growth and mortality of the recruits will be quantified using photogrametry whereby stereopairs of photographs will be taken with infra-red film. The stereopairs of photographs allow for the assessment of the change in volume of the young corals over time, whilst the infra-red film distinguishes between live and dead tissue.

The identification of a sub-sample of the recruits will be carried out using gene markers. Settling plates will be harvested at intervals of four months, the assumption being that the proportions of the different species settling are the same for each plate.

Investigation of coral population genetics

ADULTS

It might be expected that corals with either a) highly competent larve (e.g., *Pocillopora damicornis* ; Richmond, 1987) and/or b) larvae which are able to raft (e.g., *Seriatopora hystrix* ; Veron, 1986) would disperse widely and thus have high levels of gene flow. However, laboratory observations have shown that many coral species have larvae which are competent to settle within hours of release (Ayre 1991 pers. comm.). In addition, pilot studies on the genetic structure of *Seriatopora hystrix* have shown that little gene flow occurs within central regions of the Great Barrier Reef (Ayre and Dufty, 1991). The degree of connectivity between populations will influence the rate of recovery from disturbances and species with more discrete or isolated populations will take longer to recover from perturbations. Accordingly, the genetic structure of corals will be compared both locally and over the length of Ningaloo Reef.

Corals will be collected from sites which range from a few kilometres apart to hundreds of kilometres apart. Samples will be obtained initially from six backreef sites and where possible, near to the sites where the settling plates have been set up. Samples from between 50 and 100 coral heads of each species from each site will be required for the genetic analyses on the adults (1800-3600 individuals in total). Gel electrophoresis, of between 6 and 9 polymorphic loci will be used to quantify the genetic structure and estimate the connectedness of populations. This technique was chosen because it is simple and quick to use and is cost efficient.

RECRUITS

For species which have planktonic larvae and a sedentary adult stage the genetic consequences are quite different. Planktonic dispersal of larvae promotes gene exchange among populations that may otherwise be isolated whereas a sedentary adult stage is subject to localised selection which may produce genetic differences among local populations. Thus, planktonic dispersal, although causing uniformity on a large scale, can give rise to fine-scale genetic patchiness. Such fine-scale genetic variation could result from either post-settlement selection or spatial heterogeneity in the genetic composition of the supply of recruits (Johnson and Black, 1982). Thus, the genetic composition of the recruits, and not the adults, will have the major influence on the genetic composition of local populations (Watts *et al.* 1990). This influence will be ephemeral in the case of short-lived species (e.g., *Siphonaria jeanae*, Johnson and Black, 1984) or persistent for long-lived species (e.g., *Echinometra mathaei*, Watts *et al.*, 1990) or species with long generation times. It is possible to separate the effects of post-settlement selection from variation in genotypes of recruits by studying recruits over more than one generation and comparing them to the adult population (Johnson and Black, 1984). In addition, by studying the population genetic structure of adults only, it is impossible to determine whether differences detected among populations have arisen because of a lack of gene flow between isolated populations or due to selection pressures despite high levels of gene flow. Evolutionarily, these scenarios have different consequences. Differences in populations arising despite high levels

of gene flow are a result of localized adaptation and are not accumulated over time. Changes in the genetic composition of adults reflect single-generation effects of selection and recruitment (Johnson and Black, 1984). In contrast, genetic heterogeneity without gene flow allows for the accumulation of genetic differences over time and is passed on from one generation to the next. Thus it is my intention to quantify the genetic variation of recruits over a number of generations and compare their population genetic structure with that of the adult populations for each of the six species of corals.

However, before this can be done, an electrophoretic key for the recruits has to be established so that different species can be identified using gene markers. It is not possible to identify recruits to species level before at least six months of age, using current taxonomic criteria. This electrophoretic key is also necessary for the quantification of the growth and mortality of the young recruits that settle on the tiles.

Acknowledgements

This project is funded jointly by Mobil Exploration and Producing Australia and the University of Western Australia. Thanks go to my supervisor, Dr Michael S Johnson, for his support and for encouraging stimulating discussions regarding the development of the project. Conservation and Land Management has also provided support, in particular Dr Sue Osborne. This project would be impossible without field assistants. Thanks go to Dr Stephanie Turner, Alan Roberts, Craig Skepper and Carolyn Garavanta.

References

Ayre, D. J., and S. L. Dufty. 1991. Genetic variation within and among populations of corals on Australia's Great Barrier Reef. I. Genetic evidence for a bimodal pattern of larval dispersal in the viviparous *Seriatopora hystrix*. *Evolution* (In Review)

Ayre, D. J., and J. M. Resing. 1986. Sexual and asexual production of planulae in reef corals. *Marine Biology* 90: 187-190.

Forde, M. J., and C. J. Simpson. 1989. *Drupella cornus* (Roding): A voracious coral predator in the Ningaloo Reef Tract, Western Australia. Manuscript.

Harriott, V. J., and D. A. Fisk. 1987. A comparison of settlement plate types for experiments on the recruitment of scleractinian corals. *Marine Ecology Progress Series* 37: 201-208.

Johnson, M. S., and R. Black. 1982. Chaotic genetic patchiness in an intertidal limpet, *Siphonaria* sp. *Marine Biology* 70: 157-164.

Johnson, M. S., and R. Black. 1984. Pattern beneath the chaos: the effect of recruitment on genetic patchiness in an intertidal limpet. *Evolution* 38 (6): 1371-1383.

Richmond, R. H. 1987. Energetics, competency, and long-distance dispersal of planula larvae of the coral *Pocillopora damicornis*. *Marine Biology* 93: 527-533.

Stoddart, J. A. 1983. Asexual production of planulae in the coral *Pocillopora damicornis*. *Marine Biology* 76: 279-282.

Stoddart, J. A. 1989. Fatal attraction. *Landscope* 4 (4): 14-20.

Veron, J. E. N. 1986. Corals of Australia and the Indo-Pacific. North Ryde, London: Angus and Robertson.

Wallace, C. C. 1985. Reproduction, recruitment and fragmentation in nine sympatric species of the coral genus *Acropora*. *Marine Biology* 88: 217-233.

Wallace, C. C., and G. D. Bull. 1981. Patterns of juvenile coral recruitment on a reef front during a spring-summer spawning period. *Proceedings of the Fourth International Coral Reef Symposium,* Manila: 2: 345-350.

Watts, R. J., M. S. Johnson, and R. Black. 1990. Effects of recruitment on genetic patchiness in the urchin *Echinometra mathaei* in Western Australia. *Marine Biology* 105 : 145-151.